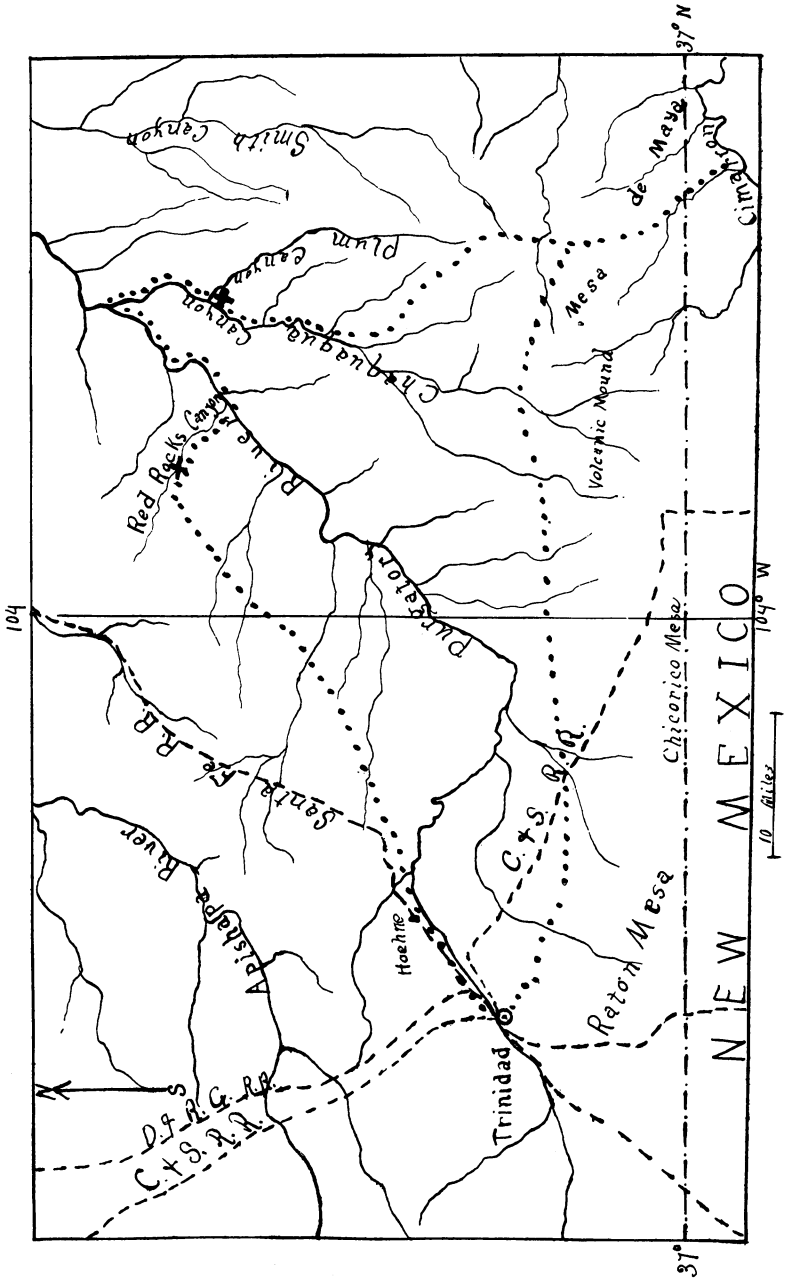
THE MORRISON FORMATION OF SOUTHEASTERN COLORADO

A CONSIDERABLE part of southeastern Colorado and northeastern New Mexico is elevated to a height of about 5000 feet above sea level. The streams of this region have cut canyons to the depth of 700 feet or more. The most notable of these is the canyon of the Cimarron in New Mexico, and that of the Purgatory, or Las Animas, in Colorado. The studies of which the conclusions are given in this paper, were carried on mainly in the canyon of the Purgatory and its tributaries, although a side trip was made to the canyon of the Cimarron. The region examined is shown in the accompanying sketch map (Fig. 1). The canyon walls are steep and bare and complete sections are easily obtainable. The lower half is red sandstone overlain with gypsum (the "Red Beds"); the surface rock is also sandstone (Dakota.) Between this upper sandstone and the gypsum is the shale formation of which I specially write. The shales are found throughout the region examined wherever the streams have cut through the upper sandstone.

Two detailed sections were taken at the points indicated on the map by a cross (×), section 1, at the junction of Plum and Chaquaqua canyons, and section 2, in Red Rocks Canyon. Since the canyons do not cut entirely through the Red Beds at any point within the area examined, it is impossible to accurately estimate their full thickness; the sections, therefore, represent only the upper part of these beds.

For some distance above the bottom of Plum Canyon (section 1) the rock is evenly stratified, ripple-marked and somewhat shaly. A limestone layer four feet thick near the bottom extends uninterruptedly for many miles and forms a convenient line of reference. Above these evenly stratified beds occurs a series of massive layers of coarse red sandstone aggregating about 250 feet in thickness. This series forms the steepest and

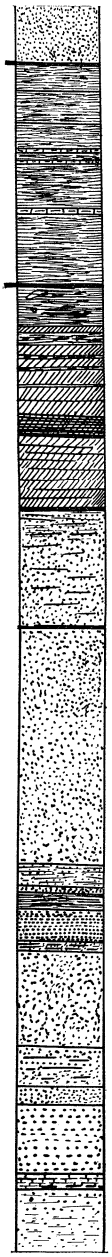

37° N
Smith Canyon
Plum Canyon
Chaquaqua Canyon
Red Rocks Canyon
Blue Canyon
Purgatoire
Mesa de Maya
Cimarron
Volcanic Mound
Chicorico Mesa
104° W
104
NEW MEXICO
10 Miles
Santa Fe R.R.
Apishapa River
Hoehne
C.+S. R.R.
Raton Mesa
Trinidad
D.+R.G. R.R.
C.+S. R.R.
37°

most conspicuous part of the canyon walls. It is notably cross-bedded and the frequent changes in the direction of bedding, as well as the frequent truncations of the cross-bedded layers, is indicative of deposition by shifting currents. The upper part of the massive series is slightly calcareous and oölitic, the little spheres of which, about one millimeter in diameter, are harder than the matrix in which they are set, and the weathered surface is thus given a "bird's-eye" appearance. The oölitic beds pass gradually upward into gypsiferous shales and thence into solid gypsum without any indication of stratigraphic break or lapse of time. No trace of fossils of any kind was found in the Red Beds.

The upper sandstone forms the general surface of the country over wide areas. The Cretaceous formations from the Ft. Pierre to the Dakota are traversed in passing eastward from Trinidad across the El Moro quadrangle which has been described by R. C. Hills,[1] and the Dakota, may be traced onward thence over the whole region studied. The Dakota is composed mainly of sandstones, although shales occur in it in places. About 150 feet from the base occurs a steel-blue shale (probably fire-clay), 2 to 6 feet thick were examined. Above this clay the formation is somewhat evenly bedded, ripple-marked and in certain places contains numerous impressions of dicotyledonous leaves. In a few places small pebbles were found near the base. The largest of these were about one fourth inch in diameter. The pebbles are so few in number that the strata containing them can scarcely be described as conglomeratic.

Between the Dakota and the gypsum at the top of the Red Beds lies the shale formation under consideration. It is constant in occurrence, although the thickness varies from place to place. At the mouth of Plum Canyon the thickness is 85 feet; in Red Rocks Canyon, it is 132 feet. In Chaquaqua Canyon, ten miles from the mouth of Plum Canyon, it is 175 feet (by barometer). The formation is composed mainly of variegated clay-shales of the variety known as "joint clay." A subordinate amount of

[1] U. S. Geol. Surv., El Moro Folio, Colo.



140 feet. Dakota. Two massive sandstone layers separated by a soft shaly layer of varying thickness; leaf impressions near the top of the upper division.

11 feet Greenwich clay shale, soft and fine grained.

12 feet dull red clay shale, soft and fine grained.

10 feet brown to yellow shale.

6 inches argillaceous limestone; numerous fine dark laminæ.

18 inches buff-colored shale.

6 inches argillaceous limestone; numerous fine dark laminæ.

18 feet variegated joint clay.

2 feet argillaceous limestone, fine grained and hard, with contorted laminæ.

30 feet variegated shales; very soft and easily eroded.

15 feet dark shales containing irregular masses of gypsum.

18 inches gypsum containing streaks of clay.

8 feet variegated shale containing nodular-like masses of gypsum which vary in size from grains to masses a foot or more in diameter. About one third of the mass is gypsum.

25 feet gypsum in well-defined layers. Often separated by layers of clay.

5 feet massive gypsum.

30 to 40 feet red gypsiferous shales, soft and regularly bedded.

60 feet red calcareous sandstone, oölitic, cross-bedded. Individual layers variable in thickness and character. Near the top it becomes shaly and passes gradually into the gypsiferous shales above.

175 to 200 feet red sandstone, massive, cross-bedded.

6 feet red arenaceous shale.

1 foot red sandstone.

4 feet fine red shale.

9 feet even-bedded red sandstone.

2 feet red arenaceous shale.

40 feet red sandstone, cross-bedded; the individual layers thin out laterally.

15 feet poorly cemented red sandstone alternating with layers of shale.

5 feet massive red sandstone.

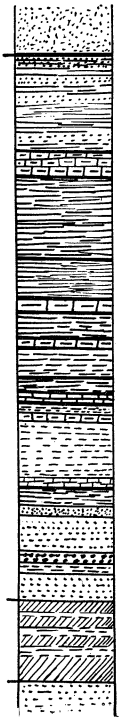
30 feet soft red sandstone containing hard layers which are ripple-marked.

4 feet hard, white, argillaceous limestone composed of numerous thin layers; greatly contorted.

15 feet red sandstone in thin flaky layers.

(River bottom.)

FIG. 2.—Section 1, near the mouth of Plum Canyon.



Dakota sandstone.

25 feet brick-red arenaceous shale, containing bands of hard, fine-grained sandstone.

3 to 5 feet reddish limestone having a conchoidal fracture and very brittle.

30 feet soft dark clay shale.

11 feet light brown clay shale.

6 inches argillaceous limestone.

7 feet brown shale.

1 foot concretionary limestone.

7 feet variegated clay shale; joint structure.

3 feet fine yellow paper shale.

6 inches argillaceous limestone, finely laminated.

18 inches fine shale.

1 foot white limestone.

15 feet variegated clay shale.

8 inches argillaceous limestone, finely laminated.

4 feet yellow shale.

1 foot sandstone containing agate either in concretionary masses half an inch or more in diameter or disseminated generally throughout the mass.

8 feet sandstone, easily crumbling; made up of thin layers.

2 feet massive sandstone, poorly indurated.

2 feet fine paper-shale.

7 feet massive sandstone, poorly indurated.

12 to 20 feet gypsum interstratified with layers of clay.

— red sandstone (Red Beds).

FIG. 3.—Section 2, in Red Rocks Canyon.

sandstone occurs in places but there seems to be no particular horizon at which this is likely to be found. In Red Rocks Canyon it occurs at the base; in Plum Canyon, none is found; in a side gulch east of Plum Canyon a brecciated layer occurs near the top containing angular fragments one quarter inch in diameter; in Chaquaqua Canyon, four miles from the mouth of Plum Creek, a coarse cross-bedded sandstone layer 15 feet in thickness occurs about 50 feet from the top; just across the canyon from this point, perhaps two miles distant, and at the same horizon, about 30 feet of limestone is found in place of the sandstone. In many places the sandstones are friable and composed of nearly pure quartz. The sand is used as a flux in assaying where pure silica is required. The occurrence of the limestones, most of which are more or less argillaceous, is as eratic as that

of the sandstones. The relative amount and position of sandstones, shale and limestones at any one point is no indication that a similar relation will be found at any other point. There is no abrupt lateral change, but the various beds blend into each other or pinch out laterally in a gradual though somewhat rapid manner, so that, while no sudden change is seen, a comparison of sections a few miles apart may show a total change in kind and relation of materials. The Dinosaur bones to be described later were found in the shales at nearly every horizon. Aside from these, no fossils were found. Careful search at every horizon failed to reveal a single invertebrate.

The three formations—the Red Beds, the shales, and the Dakota sandstone—are apparently conformable. There seems, however, to be some indication of a break between the gypsum and the shales, and still more between the shales and the Dakota sandstone. The red sandstone, as already pointed out, passes upward through shales into the gypsum by a gradual transition. There was no evidence found, at any of the places examined in detail, of a break in deposition between the red rocks and the gypsum. At the top of the gypsum the evidence is not so satisfactory in every case. In Red Rocks Canyon the change is abrupt from gypsum to sandstone; but in Plum Canyon and elsewhere the upper layer of the gypsum beds is shale containing irregular masses of gypsum. This is overlain by the variegated shales. The gypsum beds vary in thickness from 20 to something like 100 feet. In some places, at least, as shown in the sections given in this paper, the shales increase in thickness as the gypsum decreases, and vice versa. It is possible, therefore, that the gypsum beds were exposed and slightly eroded previous to the deposition of the shales. However this may be, it seems clear that the gypsum belongs to the Red Beds series, and probably marks the closing stage of the Red Beds period. If this interpretation be correct, there is no gypsum in any part of the shale formation of southeastern Colorado, so far as known. The contact of the shales with the Dakota sandstone is more plainly marked, and in places exhibits gentle undulations,

which appear to be due to erosion of the shales previous to the deposition of the Dakota.

Vertebrate fossils were found in the shales near the mouth of Plum Canyon in a number of places. No means were at hand for digging deep enough to obtain good material, but many fragments were found on and near the surface. Two of the best preserved fragments—the centrum of a vertebra and the portion

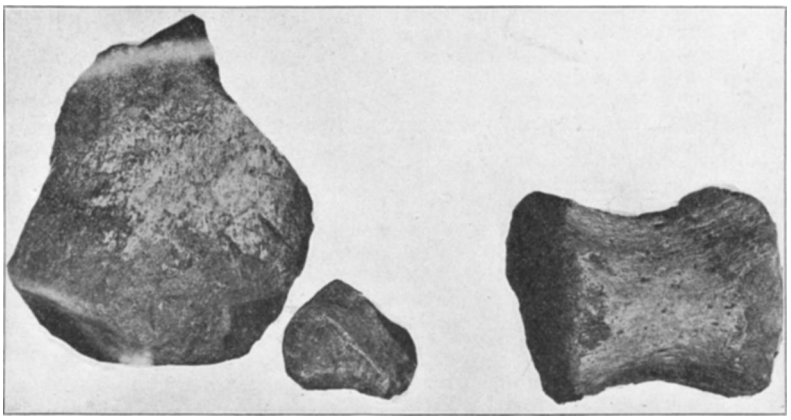


FIG. 4.

of a femur—are shown in the photograph, Fig. 4, about one eighth natural size. The dimensions of the vertebra are as follows:

Length	8	inches
Transverse diameter at ends	7	"
Depth at ends	8	"
Transverse diameter at center	5¼	"
Depth at center	6½	"
Depth of sockets, each	½	"

The fragment of the femur is 13 inches long, 12 inches wide, and 7 inches in diameter. This does not represent the thickness of the complete bone, since one side is imperfect. These bones are solid and coarse in texture. One hollow bone was also found. The piece is about 5 inches in diameter and 7 inches long, with a hollow 2 inches in diameter. The material obtained is not sufficient for generic determination, but in size, texture,

and general aspect the bones are similar to the Dinosaurian remains of the Atlantosaurus Beds of central Colorado and Wyoming.[1]

That portion of the general section for the Rocky Mountain region which is useful for present comparison is as follows: The Red Beds formation (the so-called Jura-Trias) is overlain by the Morrison formation, or Atlantosaurus Beds. The line of demarcation is drawn at the top of the gypsum beds which occur in several localities along the mountains at the summit of the Red Beds. The gypsum is regarded as marking the closing stage of the Red Beds period. The Morrison formation, which averages about 200 feet in thickness, is composed principally of variegated shales. These contain sandstones and impure limestones, the thickness and relative position of which vary from place to place, or may be entirely wanting. It is this formation which is noted for its huge Dinosaurs. Above the Morrison occurs the Dakota sandstone. It should be borne in mind that only the middle one of these three formations, the Morrison, contains Dinosaurian remains.

Since the vertebrate fossils of southeastern Colorado have not been studied, and since they are the only known fossils from the shale formation of that region, we must resort to other means of determining the age of the shales, and these will be chiefly stratigraphical and lithological, to which may be added such general paleontological evidence as may be drawn from unidentified bones.

a. As stated in a previous paragraph, the upper sandstone of the region in question was traced from a known area, and there can be little doubt, therefore, that it is Dakota. The Red Beds are in structure, color, and general aspect similar to the Red Beds of the mountain region, seventy-five miles to the west. They differ only in being composed of finer material and in being massive near the top instead of evenly stratified, as is often the

[1] Since writing this article my companion, Mr. T. A. Pierce, has again visited the bone beds and found a number of new localities where bones occur in considerable numbers. The width of the territory in which these remains are found and their number indicate that this region would yield rich rewards to the bone hunter.

case in the typical Red Beds along the mountains. The stratigraphic position of the shale formation is between the Dakota and the Red Beds. In this respect its position is identical with that of the Morrison.

b. In lithological character, the shale closely resembles the Morrison, which, in its typical areas[1], is composed of soft, variegated clay, containing more or less sandstone and limestone. A comparison of the shale formation with the typical Morrison of Colorado shows a striking resemblance. There is a somewhat greater proportion of clay than in the Morrison, as would naturally be expected so far from the mountain area, which was probably a part of the feeding ground at that time. A comparison of the Morrison (Como) of Wyoming reveals a still closer resemblance, if, indeed, it cannot be called identity. One who is familiar with the Morrison and has studied the shales of southeastern Colorado finds a striking likeness between the two in material structure and general aspect.

c. The Morrison is notable chiefly for the great Dinosaurs found in its beds, and they are not found in the Dakota above nor in the Red Beds beneath. The bones found in the shales near Plum Canyon are similar in size, texture, and general aspect to the characteristic Dinosaurs of the Morrison formation. Although none of these bones have yet been studied by a paleontologist, there is little doubt that they are Dinosaur bones, and if Dinosaurs occur between the Dakota and the Red Beds, the presumption is that the formation containing them is an equivalent of the Morrison.

The shales found in the Canyon of the Cimarron perhaps deserve separate discussion. Near the southern boundary of Colorado is the divide between the Cimarron and Purgatory rivers. On this divide, a distance of nearly thirty miles, no stream, so far as observed, cuts through the Dakota. At the top of this divide is an extensive mesa capped by flows of basalt and

[1]See U. S. Geol. Surv., Monograph XXVII, Geology of the Denver Basin, p. 52; also W. N. LOGAN, Kas. Univ. Quarterly, 1900—"The Stratigraphy and Invertebrate Faunas of the Jurassic Formation in the Freeze-Out Hills of Wyoming," pp. 113-115.

known as Mesa de Maya. It is a part of the volcanic region extending from the mountains eastward along the southern border of Colorado. This mesa is separated from the equally elevated region of northern New Mexico by the canyon of the Cimarron, which is cut not only through the basalt and the Dakota, but deep into the Red Beds. Here, as further north, a shale formation lies between the Red Beds and the Dakota. At the one point studied gypsum occurs near the top of the Red Beds, but a thick stratum of red sandstone lies between it and the overlying shales. The shales correspond closely in character and general appearance with those further north, although they are more arenaceous and thicker (about 350 feet). No fossils of any kind were found, but enough was seen of the formation to warrant the inference that it is probably the same as the formation which occurs in the same position in the canyon of the Purgatory, thirty miles further north, viz., the Morrison.

SUMMARY

1. From the foregoing considerations it appears that the stratigraphic, lithologic, and paleontologic evidence all point to the inference that the shales of southeastern Colorado are of Morrison age. It is inferred, furthermore, that this formation extends from its line of outcrop along the flank of the Front Range, underneath the Dakota, as far east as Smith Canyon, about seventy-five miles, and as far south as the canyon of the Cimarron. How much further it extends in these directions is not determined.

2. Although there are gypsiferous shales lying between the gypsum and the fossiliferous shales, which might seem at first thought to form a transition, it is thought that the line of demarcation should be drawn at the top of the gypsiferous shales. If this division be correct, there is no gypsum in the Morrison formation of southeastern Colorado. In this it differs from that formation as reported from some localities. The gypsum is here considered as belonging to the closing stage of the Red Beds period.

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